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Energy Planning in the Arab World

by

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Energy planning in the Arab world

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Efficient use of energy is of interest to the energy surplus regions as well as the energy deficit regions. Similarly concern about energy conservation is not confined to the industrially developed regions of the world. This article discusses energy planning from the Arab point of view. A framework for Arab energy modelling is first described. Then the application of a computer model – that of Mesarovic and Pestel – to Arab energy planning needs is discussed and some of the results are presented. Finally current priorities in Arab energy modelling studies are outlined. The Appendix surveys some existing models which address regional and international energy problems.

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Over the last decade or so, global and regional issues such as population growth, food shortage, energy shortage, and economic and social development have been the subject of substantial international research programmes. This effort has led to conceptualization of problems and possible solutions, as well as to the realization of the considerable difficulties involved.

In this paper we concentrate on energy issues related to the Arab world, as a developing region, at the regional as well as national levels. One cannot ignore the linkages between Arab countries and the rest of the world. Energy policies within the Arab world affect, and are affected by, corresponding policies outside the Arab world. This study therefore examines regional and global energy issues in general and their importance to the Arab nations.

A framework for Arab energy studies

There is considerable interest in energy problems at the global and regional level and the Appendix surveys some studies of energy planning at this level. There is also a class of studies related to national energy modelling.[1] With the exception of the Mesarovic–Pestel study, however, all studies have been initiated, carried out, completed and implemented outside the Arab world.[2]

The issues related to energy problems in the Arab world are of importance not only for Arabs but also for many other nations who depend on primary energy sources imported from the Arab region. Thus a framework is needed for the study of Arab energy planning in a global context.

Energy planning has two important aspects:

- Topics related to the development of new sources of energy and the substitutability of oil by these sources. This involves the problems of new energy sources and the transition, be it partial or complete, from traditional sources of energy to new ones.
- Issues related to oil and gas prices, their effect on world demand and on the rate of development of new energy sources, the political value of oil and gas as bargaining tools in the hands of the Arabs, and the use of oil revenues to develop and perhaps change the economic structures of Arab countries.

Energy planning should be handled on three different, but closely related levels: short term, medium term, and long term.

[1] See, for example, G.B. Dantzig and S.C. Parikh, *On a PILOT Linear Programming Model for Assessing Physical Impact on the Economy of a Changing Energy Picture*, Technical Report SOL 75-14, Systems Optimization Laboratory, Stanford University, Stanford, CA, 1975, E.A. Hudson, D.W. Jorgenson, and K.C. Hoffman, *Energy Supply Model*, Brookhaven Laboratory, Upton, NY, 1976, and C. Robinson, 'Overview of the UK energy position to year 2000 and economic implications', paper presented to the Operational Research Society conference, Swansea, 21-25 September 1976.

[2] M. Mesarovic and E. Pestel, 'Multi-level computer model of world development systems', paper presented to IIASA symposium, Laxenburg, Austria, 29 April-3 May, 1974.

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Short-term energy planning

This is mainly concerned with management of existing energy sources, as well as transportation of energy to final consumers. The timescale is confined to one year, but perhaps divided into two or three time periods according to the nature of the energy system. The main features of such a model must include: rates of oil production from fields; rates of exporting/importing crude oil; quantities of final products exported/imported; quantities of final products transported to consumers (eg residential users, industrial and commercial users, transport); rates of natural gas production; export/import of liquefied natural gas; use of natural gas as a source of energy in coal mining; coal import/export; coal transportation to final consumers; rates of uranium and other nuclear materials production; rates of nuclear power generation and regeneration of nuclear fuel; solar energy generation and transmission of solar generated electricity to final consumers.

Economic as well as technical aspects of these topics must be considered. The purpose of the short-term plan may be, for example, to fulfil the needs of energy consumers at a minimum overall cost to the energy producing sectors.

Although models of this type have been developed for the USA, Germany and the UK, I am not aware of any model developed for an Arab country.

Medium-term energy planning

The scope of medium-term planning is 5-10 years. It is concerned with capacity expansion and replacement of existing production and processing methods. As a balance between energy demand increase and capacity increase is hard to achieve capacity is increased with the possibility of either shortage in supply or underutilization of capacity for some years until demand catches up. From the investment planning point of view the underutilized capacity represents idle capital which could have been invested somewhere else. This idle capacity should be used to produce and sell at the marginal cost if there is enough demand outside, or be penalized at the international interest rate.[3]

Replacement of existing production and processing capacities also comes under medium-term planning. From the accounting point of view the production machinery's life comes to an end after some period, say 20-30 years. At this stage, for book-keeping purposes, the value of the machinery is what one could get for it if sold, either to other producers or as scrap. At this stage we are faced with either replacing the unit by another identical one or by one which is more technologically advanced, of bigger production capacity and perhaps cheaper to purchase and operate. The question of how replacement is carried out is an intricate one and needs good technological knowledge as well as detailed economic analysis. New investment opportunities for further utilization of primary energy sources are also considered under medium-term planning as long as they do not involve technological developments or large uncertainties.

There is a need to develop medium-term planning for the Arab world. This would have benefits in many areas, for example:

- better balance between capacity increase and investment in new technology;

[3] See G. Så, *Concave Programming in Transportation Networks*, unpublished PhD thesis, MIT School of Management, 1968.

- better division of labour between the Arab countries to avoid duplication (for example in the petrochemical industries);
- better utilization of existing spare capacity.

Long-term energy planning

The main concern here is issues whose outcome is not likely to have an effect within the next 5-10 years. Such issues include: the depletion of primary energy resources; accumulation of pollution effects on the environment; effects of developments in new energy sources and their substitution for traditional sources. As the revenues from oil sales constitute a major source of finance for the Arab countries it is necessary to promote efficient use of these revenues in economic and social development. Economic development could be achieved via one or both of the following paths:

- development of existing sectors to maximize their output;
- addition of several new sectors, development of the new and the old sectors in a balanced way and maximization of their output.

Either path and especially the second one, requires that society accepts the change and consequently provides (and perhaps imports) some factors of production for the developing sectors. Problems of human resource development, training, technology transfer and labour mobility require a relatively long period (probably more than ten years) for their solution. These problems should be studied within the long-term planning context.

The Mesarovic–Pestel model and Arab long-term energy planning

The Mesarovic–Pestel (M–P) energy model was intended to study world problems on a global level.[4] Two important issues were:

- planning for the production and transportation of foodstuffs necessary to guarantee at least subsistence levels for all countries; and
- planning for efficient utilization of primary sources of energy with specific reference to oil and to the matching of price and production rates.

In the M–P model the world is divided into ten regions: North America; Western Europe; Japan; Australia, South Africa and the rest of the market economy developed world; Eastern Europe including the USSR; Latin America; North Africa and the Middle East; Tropical Africa; South and South East Asia; and China. The time horizon of the model is 50 years, from 1975 to 2025, and past data are based on the time period 1950-1965.

Description of the Mesarovic–Pestel world oil model

The model consists of the following three sub-models:

- economy sub-model;
- population sub-model;
- oil sub-model

The oil sub-model consists of three components: oil demand; oil production; and world oil trade. The interlinkages between the oil sub-

[4] M. Mesarovic and E. Pestel, *op cit*, Ref 2.

model and the two other sub-models use the Gross Regional Product (GRP) which is calculated in the economy sub-model, and the total population, which is calculated in the population sub-model, to estimate total energy demand by a functional relationship. The parameters of this functional relationship vary from one region to another.

Once total energy demand is calculated, the proportion of oil demanded is calculated by the use of the Linden curve, which estimates oil-based energy demand from total energy demand.[5] The parameters of this curve vary, in general from one world region to another.

In the oil production part of the oil sub-model the policies and economics of oil production from oil fields or extraction from oil shale and tar sand are considered. Oil conservation and/or embargo policies also affect the rate of oil production and were treated as exogenous policy parameters in the model. Again these policies can vary from region to region.

By comparing oil production in each region with the quantity of oil demanded in the region, we can decide whether it is an oil deficit or an oil surplus region. This information is fed into the world oil trade component of the oil sub-model and gives one of the following results:

- Oil production falls short of the actual demand. In this case the quantities received by various regions are reduced in proportion to their share of total demand.
- Oil produced (or planned to be produced) exceeds demand. In this case the quantities produced by various regions are cut in proportion to the region's share of total production.
- Oil demanded equals oil produced (or planned to be produced). In this case there is no adjustment.

As a result of oil sales, at a predetermined oil price which is exogenously fed into the model, money is paid to the selling region either in the form of capital goods, consumption goods or bank credit. The oil producing region may recycle oil dollars back to oil consuming regions through various forms of investment. It is also possible that this money is invested within the oil producing region itself for the purposes of economic and social development. The effects of raising the oil price, the substitution of oil by other sources of energy and the cost of developing and implementing new energy sources are not considered in the M–P model. However the model caters for both oil demand reduction and oil supply increase due to an increase in oil price. These effects are described by two exogenously determined factors and are fed into the model. The same applies to oil conservation policies which are expressed in the model as a percentage of annual demand. If the oil producing countries raise the price of oil, the oil consuming countries are likely to retaliate. One form of retaliation is raising the cost of investment goods supplied to the oil producing countries, especially if the latter are in the developing stage. The model takes care of this, but requires that the retaliation measure is determined exogenously, and that it should be expressed as a percentage of the prices of investment goods.

The inputs to the M–P model are of two types: data base information and scenario information. Data base information includes non-policy data, various parameters, and coefficients of various functional relationships. Scenario inputs include the policy

[5] The Linden curve is described in J.D. Parent, and H.R. Linden, *A Study of World Crude Oil Supplies*, mimeo, Institute of Gas Technology, Chicago, undated.

Table 1. Scenarios which were tested for the Middle East region.

Policies and Parameters	Values: Standard scenario	H1 scenario	H2 scenario	SME2 scenario
Potential resource estimates[a]	2 500	3 000	3 000	3 000
Oil demand reduction with price increase	0.225	0.45	0.45	0.225
Oil supply increase with price increase	0.75	0.50	0.75	0.75
Annual increase in oil prices	—	5%	3	—
Upper limit on oil prices ($/barrel)	13.5	16.5	13.5	10.5
Oil consumption reduction	—	7.5%	15%	—
Relationship between oil prices and investment good cost	—	100%	50%	—
Desired economic growth	4%	4%	5%	5%
Population policy[b]	Medium	Medium	Efficient	Medium
Monetary recycling	Fair	Efficient	Poor	Fair

a 10^9 bbl

b Medium: world population is 8.58×10^9 in 2025. Efficient: world population is 6.53×10^9 in 2025.

and decision parameters, eg oil demand reduction with price increase, oil supply increase with price increase, annual increase in oil prices, relationships between oil prices and investment goods cost, desired economic growth rate, and degree of oil dollar recycling efficiency. There are two ways of feeding the values of the scenario input into the model: qualitatively (ie using verbal descriptions such as 'high', 'low' and 'medium') and quantitatively (ie using actual values). The input package translates the qualitative descriptions into quantitative values to be used by the model. The outputs from the model are projections of population and projections of various economic and energy indicators. These include:

- world oil deficiency and surplus;
- gross regional product for various regions; and
- oil dollars accumulated.

Implementation of the Mesarovic–Pestel model for the Middle East

The M–P model was installed on an ICL 1906S in Cairo and used to test some scenarios prepared by senior officials of the energy sector in the Arab world. It has proved to be a valuable tool for assessing the policy decisions and for comparing the implications of various policies related to the energy sector as well as other policies. Table 1 summarizes two of the scenarios (H1 and H2) which were prepared by Arab officials together with two of the scenarios supplied by the Mesarovic and Pestel group (STANDARD and SME 2). Figures 1, 2 and 3 show the output obtained. This ouput leads to the following conclusions (amongst others):

- The scenarios supplied by Mesarovic and Pestel are rather pessimistic (in relation to rates of oil production) compared to what Arab officials would have actually decided upon. The oil deficit estimated with the Mesarovic and Pestel scenarios (STANDARD and SME 2) is much more than that which results from the Arab scenarios (H1, H2). From Figure 1 it is obvious that the Arab policies lead to ample supplies in the years beyond 1980 rather than drastic deficits beyond the year 1990 as was estimated on the Mesarovic and Pestel scenarios.
- Regardless of which scenario is followed, the developing regions (Latin America, North Africa and the Middle East, Tropical

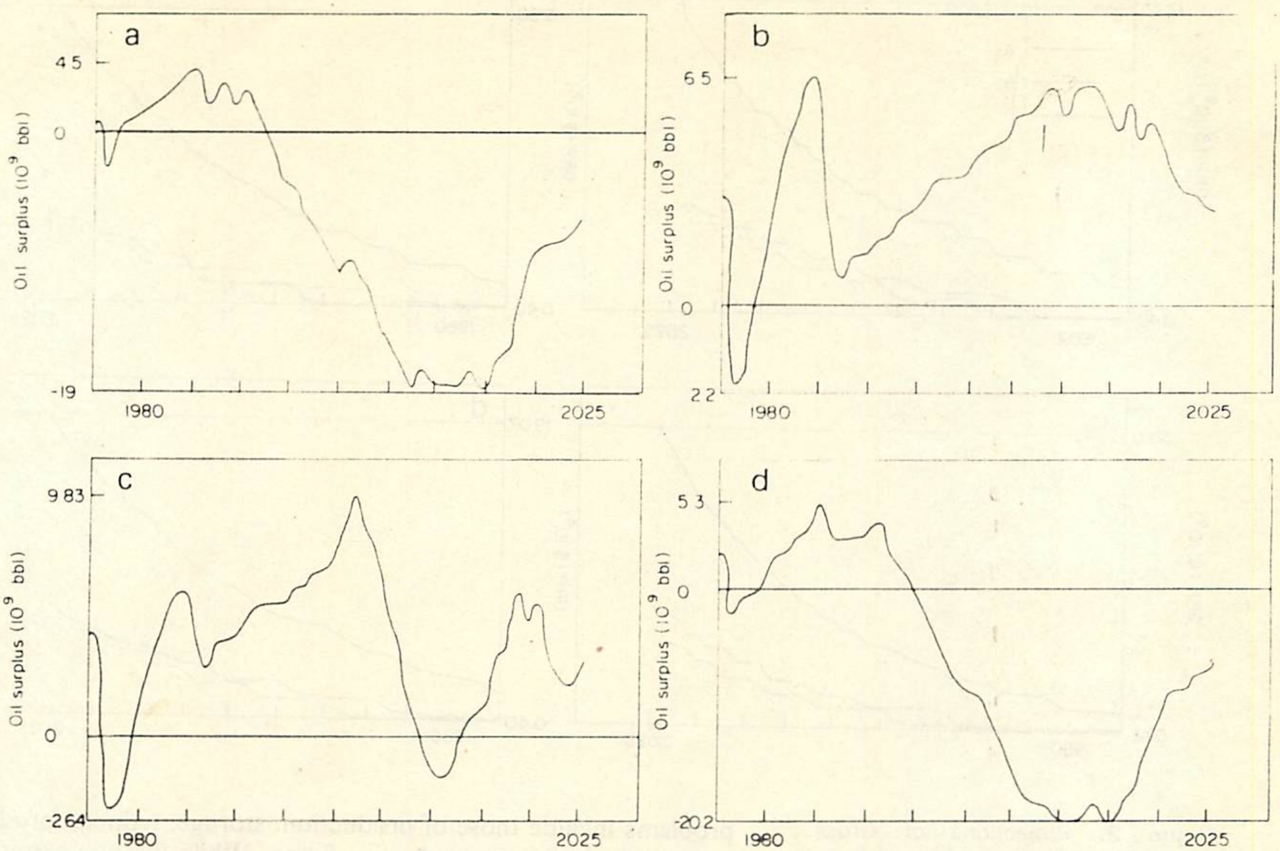

Figure 1. Projections of world oil deficit and surplus. (a) STANDARD scenario, (b) H1 scenario, (c) H2 scenario and (d) SME 2 scenario.

Africa, and South and South East Asia) always have the lowest GRP, the developed regions always maintain the highest GRP and Eastern Europe (including USSR) and China have GRPs between these limits but very close to those of the developing regions (see Figure 2).

- With the Arab scenarios (H1 and H2), oil dollars accumulated and capacity accumulated are much less than in the case of the Mesarovic–Pestel scenarios. However the capacity accumulated in the Middle East is always lower than the oil dollars accumulated (between 1/3 and 1/5). This may be due to constraints imposed by the absorption capacity of the economies of Middle East countries and draws attention to the possible need for changing the structure of Middle East economies.

The present programme of Arab energy studies

In conclusion I shall list the topics which are being investigated in the course of current research on Arab energy planning:[6]

- Short- and medium-term energy problems at the national and regional levels, eg present energy generation strategies, oil export strategies, the mechanisms of the oil market, and the international oil pricing system. Activities in this area should include assembly of studies by OAPEC, OPEC, OECD, EEC and others, *which* are related to these topics.
- Short-term planning and management of the energy sector at the national level. This topic should cover the problems of oil exporters as well as the non-exporters. For exporters, the

[6] This programme is currently being carried out by a study group working at the Institute of National Planning in Cairo in collaboration with several Egyptian, Arab, Arab regional, and International Organizations.

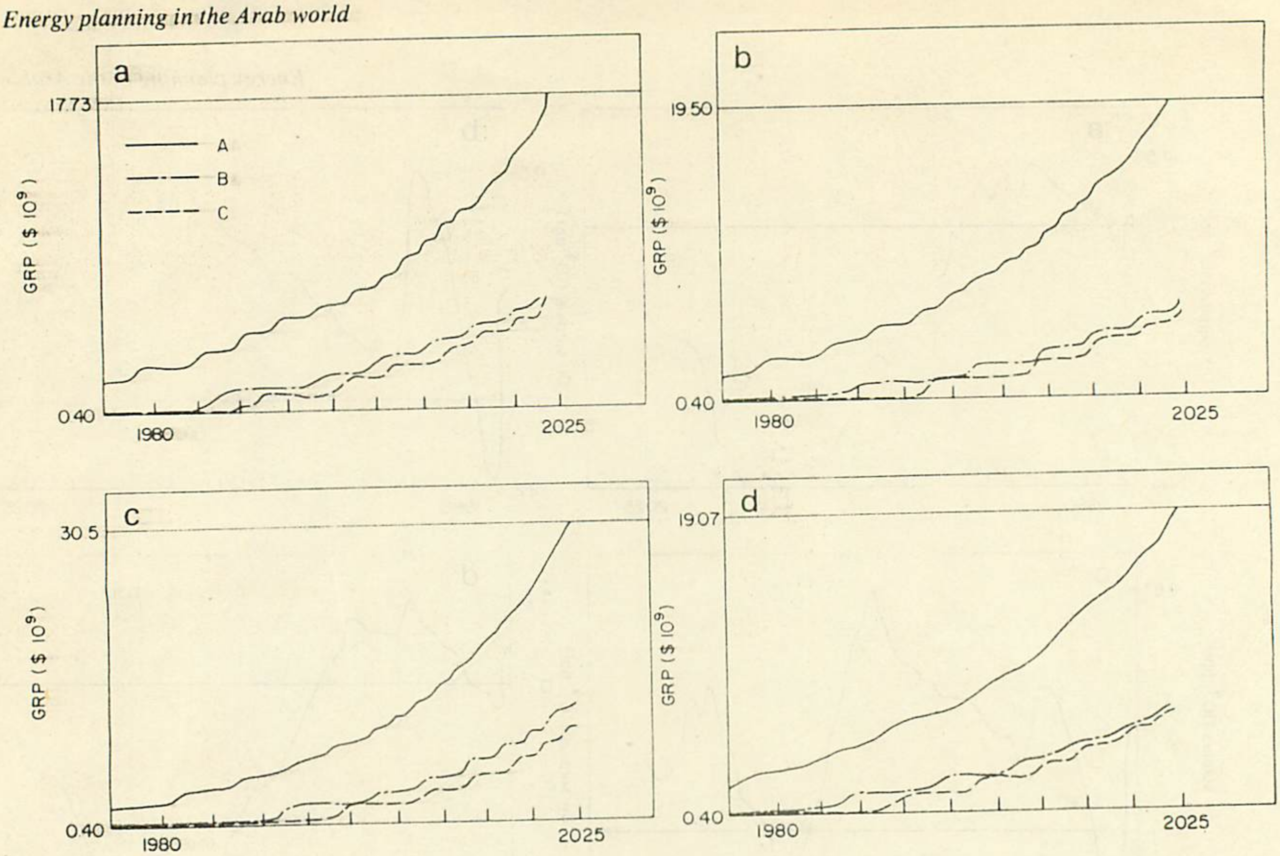

Figure 2. Projections of Gross Regional Product for various regions. (a) STANDARD scenario, (b) H1 scenario, (c) H2 scenario and (d) SME 2 scenario.

A = North America + Western Europe + Japan + Australia, South Africa and the rest of the developed market economies.
B = Eastern Europe including USSR + China.
C = Latin America + North Africa and the Middle East + Tropical Africa + South and South East Asia.

problems include those of production, storage, refining, products export, crude export, and price fixing. While for non-exporters, the problems are mainly concerned with efficient use of oil and import balancing.

- Medium-term studies of oil development and use in different parts of the world which will affect the Arab world. This includes programmes of investment in the oil sector, programmes of distribution, anticipated costs of investments, studies related to general distribution of oil and natural gas and studies of changes in markets and market allocation. These studies are to be based on the national and international programmes, including oil conservation and substitution policies, in oil importing countries.
- Models of long-term developments in energy sources aimed at examining the effect of nuclear energy, solar energy and other energy sources on the position of oil.
- Long-term technological studies covering, for example: oil extraction from offshore fields, shales and tar sands; gasification of coal; technology of machinery designed to use electricity rather than oil and its impact on manufacturing industries and the sectors which serve or supply them with factors of production; technology of nuclear energy development and its impacts, eg suitability, medium- and long-term capacity, cost, and limitations due to environmental and cost factors.
- Long-term studies related to solar energy, tidal energy and wind energy. These studies should concentrate on appraisal of available technology and the economics of developing these sources.

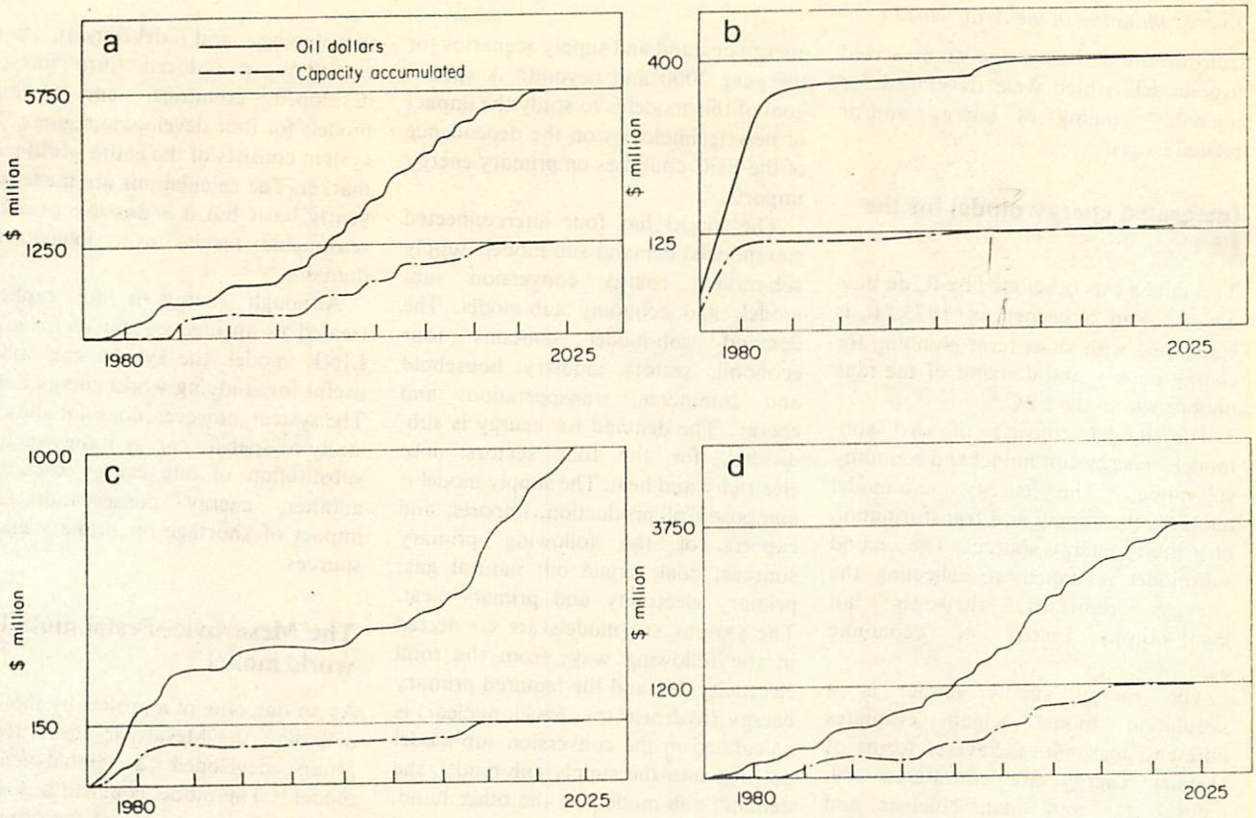

Figure 3. Oil dollars accumulated and capacity accumulated in the Middle East. (a) STANDARD scenario, (b) H1 scenario, (c) H2 scenario and (d) SME 2 scenario.

- Large-scale international and national investments related to energy production.
- The development of alternative energy sources, oil price fixing and stabilization.
- Effects of energy supply on industrialization and urbanization, including social effects and the mix of manufactured goods.
- Energy as a factor in the development of industry and communities.
- The effect of energy cost on the feasibility of exploiting natural resources, particularly deep seabed resources.[7]

[7] The exploitation of these resources is much more attractive with low energy prices than with high prices.

Appendix: Summary of some energy planning studies

Interest in the planning of energy production and consumption started long before the 1973 energy crisis. Since the crisis however, more attention has been given to the international and global implications of OPEC and OAPEC oil markets. The control of oil prices by the oil producing countries has resulted in some counter measures on the part of oil consuming countries to guarantee their share of oil as well as to compensate for increases in oil prices.

As a result of this producer–consumer policy, of possible embargo rather than co-operation, it was considered necessary to try to answer questions like: 'What effect would an increase in oil price have on the economy and the consumption of energy?', 'Which sectors would be affected most by the increase?', 'What would be the effect of a temporary interruption in oil supply?', 'What measures would have to be taken to limit domestic production?', 'What possibilities are there for substitution of oil by other sources of energy and what are the economic aspects of such a substitution?'

Questions such as these necessitated the development of models, which include not only the energy sector but also its relationship to other sectors, eg population, economic activities, transportation. Below are summarized five models which were developed for regional planning of energy and/or related issues.

Integrated energy model for the EEC

This model was developed by R. de Baw and F. Van Scheepen in 1973. It is concerned with short-term planning for energy supply and demand of the nine nations within the EEC.[8]

The model consists of two sub-models: energy sub-model and economy sub-model. The energy sub-model analyses the supply and transformation of primary energy sources. The second sub-model is aimed at collecting the energy demand through an input–output matrix of economic activities.

The energy supply model is a simulation model which evaluates different possibilities. Several forms of primary energy are considered: oil, natural gas and coal. Nuclear and hydroelectric energy supplies are assumed to be exogenous in the short term. The constraining elements are: electricity generating capacity; available means of energy transmission; and capacities for primary energy transformation (eg oil refining).

The relation between the economic activities and the energy sector are represented by two sub-models within the economy sub-model. These sub-models are:

- a sub-model of household consumption, which gives the quantities of the consumed energy as a function of income and prices; and
- a sub-model of external trade, which indicates modifications of the EEC position in the world context.

The goal of the model is to answer questions about the effects of income on energy prices, effects of temporary interruption in the energy supply, effects of an increase in prices on various economic sectors, and measures to limit domestic production.

Energy simulation model for the EEC

This model studies the impact of different supply strategies and develops energy demand and supply scenarios for the year 2000 and beyond.[9] A special goal of this model is to study the impact of new technologies on the dependence of the EEC countries on primary energy imports.

The model has four interconnected sub-models: demand sub-model; supply sub-model; energy conversion sub-model; and economy sub-model. The demand sub-model contains four economic sectors: industry; household and commerce; transportation; and energy. The demand for energy is subdivided, for the four sectors, into electricity and heat. The supply model is composed of production, imports, and exports of the following primary sources: coal; crude oil; natural gas; primary electricity and primary heat. The various sub-models are connected in the following way: from the total electricity demand the required primary energy (hydroelectric, fossil, nuclear) is calculated in the conversion sub-model and fed into the supply sub-model; the demand sub-model, on the other hand, is connected to the economy sub-model through the GNP growth rate by functional relationships. The costs of imported primary sources affect the GNP growth rate.

The model was applied to the nine nations of the EEC for the period 1960-2000. The simulation model was written in DYNAMO III following the systems dynamics approach. Functional relationships are given in the form of tables and time series are generated by a loop structure and time variant growth rates. It was noticed that the results suffer from poor knowledge of functional relationships.[10]

The LINK system

The LINK system was developed by the study group headed by L.R. Klein at the University of Pennsylvania.[11] The system was intended for forecasting and policy analysis of the world trade situation through careful linkage of national economic models. It has been used to estimate many international multipliers in order to study the effects of alternative national policies and to simulate various exchange rate configurations.

The LINK system is composed of separate models for thirteen countries (developing and developed), some equations in reduced form for two developed countries, and regional models for four developing regions. The system consists of the entire world trade market. The calculations are made on a yearly basis but it is possible to obtain reasonable results over longer time domains.

Although energy is not explicitly treated as an independent sector in the LINK model, the system can still be useful for studying world energy issues. The system, however, does not allow the study of specific energy issues such as: substitution of one energy source by another, energy conservation, and impact of shortage on primary energy sources.

The Mesarovic–Pestel multi-level world model

As an outcome of a project by the Club of Rome, the Mesarovic–Pestel (M–P) group developed a global energy model.[12] The model is aimed at helping decision makers to assess the results of decisions related to oil prices, oil production rates, energy conservation measures, etc. The first generation of the energy model is available and was implemented in several parts of the world, including Venezuela, West Germany, Iran and Egypt. The model is of the discrete simulation type. It consists of three sub-models linked together: energy sub-model, economy sub-model, and population sub-model. Yearly estimates of population size and of gross regional product are obtained from the population and the economy sub-models. Energy demand is then calculated via a functional relationship. The proportion of oil in the total energy demanded is calculated through the use of a curve developed by Linden and Parent.[13] From this point the energy model becomes an oil model; it investigates only issues related to oil as a primary source of energy and ignores other sources of primary energy and the implications of oil policy for the use and development of other sources.

The Leontief 'Future of the World Economy' study

This study was prepared by a group headed by W. Leontief under the auspices of the UN.[14] The aim was to study the future of the world economy. The study includes, as a principal feature, a set of alternative projections of the demographic, economic and environmental states of the world in benchmark years 1980, 1990, and 2000.

Table A1. Regional grouping used in the Leontief study.

Group	Region
Developed	North America Western Europe (high-income) Soviet Union Eastern Europe Western Europe (medium-income) Japan Oceania Africa (medium-income)
Developing (resource rich)	Latin America (low-income) Middle East Africa (tropical)
Developing (resource poor)	Africa (arid) Asia (low-income) Asia (centrally planned) Latin America (medium-income)

The world is divided into 15 regions classified in the following three main groups: developed, developing group I (resource rich), and developing group II (resource poor). Table A1 shows the regions and the group each belongs to. Each region is described in terms of 43 sectors of economic activities grouped in three major groups as follows: agriculture, mineral resources (which include oil, natural gas, and coal), and manufacturing activities. The model brings the regions of the world together through a complex linkage mechanism including exports and imports of some 40 classes of goods and services, capital flows, aid transfers, and foreign interest payments. The model describes emissions of eight types of major pollutant and five types of pollution abatement activity. The principal environmental policies considered are those concerning pollution, constraints on the extraction of mineral resources and constraints on food production. Based on results of model computations the study investigates, in a very broad framework, issues related to: food and agriculture; mineral resources (including oil, natural gas, coal); pollution and pollution abatement; structural changes in the economies; balance of payments; and changes in international economic relations.

The model used for the study is a simulation model composed of input–output (I–O) models of various regions linked together. As a result, 15 regional sets are obtained each consisting of 175 equations, which are mostly but not exclusively linear, and 269 variables. 229 variables are region specific and 40 are export/import variables. When the system is solved, 94 variables for each region are specified *a priori*, these include:

- target variables which describe the future state of the economic system (such as: levels of per capita GDP, private and public per capita consumption and their respective rates of growth); and
- a combination of causal instrumental factors (such as: domestic savings, external balance of payments, labour force participation, price of raw materials and so on).

This is done in such a way that the result is a number of linear equations in the same number of variables. Thus the system can be solved. It was found that the gap in per capita gross product between the developed and the developing countries (which amounted to 12 to 1 on average in 1970) is not likely to start diminishing by 2000 even if growth rates in the developed countries were retained at their values observed during the last two decades while those of the developing countries were increased annually by about 3.5%. Thus in the basic scenarios used, growth rates of gross product per capita were set in such a way as to roughly halve the income gap between the developing and the developed countries by 2000, with a view towards closing it completely by the middle of next century. It was found that the income gap is hardly reduced at all if the developing countries do not make provisions for: substantial increases in internal or external investment rates, and major increases in export shares and import substitution. This major finding helped in clarifying how the world can realize the aims stated in the Declaration on the Establishment of the New International Economic Order.

The IIASA energy model

This model is currently being developed by the energy group headed by W. Häfele at IIASA.[15] The model is a world model aimed at studying the strategies for energy transition and their impact on economies. This work is a culmination of many efforts aimed at studying the technical and economic feasibility of transition from fossil energy to nuclear, solar, and other sources of non-fossil energy.

The main purpose of this model is to assess the impact of new energy sources on the economy and the environment. It is obvious that the development of an easy, safe and cheap source of nuclear or solar energy needs substantial financial resources for research. When and if such a source exists there is the need to manufacture it (an additional requirement on manufacturing industries) and also there is a need to modify the energy consuming machinery to accept this new form of energy. Obviously this requires financial resources as well as changes in technology; additional investments are necessary which the economy may, or may not, be able to meet. These changes and/or additions may need some time to be implemented and there is a need to couple this with a model of the economy which takes into consideration the time factor. The resulting pollution from extensive use of new energy sources (eg nuclear parks containing fast breeder reactors), and their impact on the environment should be carefully assessed. The IIASA model is composed of several sub-models which are aimed at investigating some of these issues.

There are six world regions in the IIASA model. In this context, however, a world region refers not so much to a geographic region as to countries with similar resources and economic characteristics. The six regions are:

- region with a highly developed market economy and energy resources;

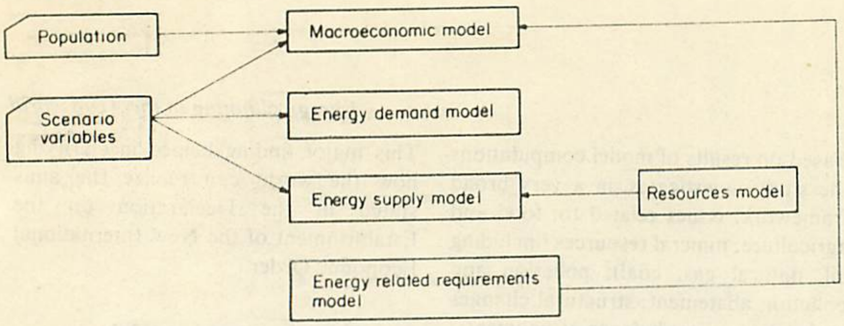

Figure A1. Links between sub-models in a regional module of the IIASA energy model.

- region with a highly developed market economy, without energy resources;
- region with a highly developed centrally planned economy and energy resources;
- region whose economy is developing and which has large energy resources;
- region whose economy is only developing but which has some energy resources, and significant population growth; and
- region whose economy is only slowly developing and which has no energy resources but significant population growth.

Each regional module is composed of the following five models interlinked together (as shown in Figure A-1): energy supply model, energy demand (end use) model, a macroeconomic model, a resource model, and a model to identify the requirements (from investment, labour, and land) for the optimal energy strategies identified by the supply model.

The model is in modular form. Each region has its own module with all interactions with other regions taken as exogenous variables. The modules for regions 1, 2, 5 and 6 have been completed with the USA, West Germany, Egypt, and India as representative states. Modules for other regions are currently being built.

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[8] R. de Baw and F. Van Scheepen, 'Problems posed by the conception and utilization of an integrated model concerning the energy of the European Community', paper presented to ECE Symposium on Mathematical Models of Sectors of the Energy Economy, Alma-Ata, 1973.

[9] H. Neu, *A Dynamic Model for Simulating Future Energy Demand and Supply in the European Communities, Scenarios for the Year 2000 and beyond*, Euratom Report, 1975.

[10] *Ibid.*

[11] L.R. Klein, *International linkage of national economic models*, Amsterdam 1973.

[12] M. Mesarovic and E. Pestel, *op cit*, Ref 2.

[13] J.D. Parent and H.R. Linden, *op cit*, Ref 5.

[14] W. Leontief *et al*, *The Future of the World Economy*, Oxford University Press, New York, 1977.

[15] W. Häfele and A. Makarov, 'Modelling of medium and long range energy strategies', paper presented at the Workshop on Energy Strategies, IIASA, Laxenburg, Austria, 17-18 May 1977.